BENEFITS OF WOOD BIOMASS MAKE CULTIVATION ESSENTIAL

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Plant materials, or biomass, already contribute significantly to energy supplies throughout the world. Even in the United States where such usage is confined primarily to fuelwood and wood wastes burned by wood processing plants, the quantity of energy generated from biomass is important — over 1.5 percent of the total consumption in the U. S. (currently 75 quads of energy). Although significant, such figures show the U. S. to be far from the goal of certain other countries to make biomass fuels a large component of energy use. Some examples:

1. Brazil is attempting with high capitalization and technology to produce ethanol from crops grown for that purpose. The ethanol is intended as a major source of liquid fuels for automobiles. Their program had progressed to the point where several large distilleries are already in production. The crop for this purpose is manioc, a root crop which is adapted to relatively infertile soils and can be grown satisfactorily without irrigation. Livestock production is incorporated into these operations in order to utilize the waste and increase efficiency.
2. Red China has begun a program to provide small scale units on individual farms for production of methane through anaerobic decomposition of farm manure and human wastes. The methane produced would be used at the farmstead for cooking and other purposes.
3. Perhaps the most optimistic program for energy production from biomass is in Sweden. In April, 1980, at a Conference in Atlanta, Georgia, I listened to representatives of that country forecast that by the year 2015 Sweden would have the potential to produce up to 60 percent of its energy from biomass with 45 percent from biomass farms using willows and 15 percent from conventional forestry residues. This would allegedly be achieved with a continued increase in the country's standard of living and yet with only 6 to 7 percent of the total land of Sweden being devoted to the willow plantations.

Potential in the United States

Most analyses show a substantial potential contribution to future U. S. energy consumption from biomass (about 5 percent). Such energy would be in the form of fuelwood for homes; forest and mill wastes used onsite for mill power and cogeneration of electricity for nearby communities; agricultural and food processing wastes used on the farm and at the food processing plants, forest, farm, and city wastes used for electrical production and gasification at central locations; and biomass produced from both terrestrial and aquatic environments also used in central systems for production of electricity and gas.

Within the United States there are considerable differences among regions with respect to options for biomass production and energy recovery. For instance, the Northeast with rural populations, cold winters, and abundant woodlands already uses large quantities for fuelwood for home heating. Also, chips from natural stands of small dimension hardwood stands are likely to be utilized in small centralized systems for energy conversion.

Two clones of poplar hybrids at 1½ years illustrate experimental biomass plantings for energy or fiber. Trees were spaced 4 feet apart.

The Southeast, also with a considerable rural population, has a relatively smaller potential for fuelwood usage. This area also has an abundance of low quality natural hardwood stands which could be chipped and used in central systems. Following the harvest of such forests, the material for such systems could be provided from biomass farms using rapidly growing species.

The Pacific Northwest has a high proportion of productive forest land and also relatively high timber and pulp chip values due primarily to export markets. If these timber values remain high, the region is likely to be hard pressed to provide future fuelwood needs for home heating. Together, the high projected demand for timber, pulp, and firewood in the Pacific Northwest may make high production tree plantations more economically feasible than in other regions. Such plantations could be sufficiently versatile to provide fiber, cordwood, or biomass fuel depending upon needs and markets at harvest. Such plantations are potentially suitable for much of the underused and marginal agricultural lands and certain forest lands in the Pacific Northwest.

Increasing yield potential of woody plants

Rapid growth is not necessarily of adaptive significance to trees; rather, such characteristics as wind firmness, disease and insect resistance, and drought resistance are likely more important in natural selection since with such traits a tree can survive long enough to be effectively reproductive. For instance, we now realize that Douglas fir, although active photosynthetically during the winter months, frequently closes its stomata during warm and sunny periods of the day even though soil moisture supplies may be adequate for continued transpiration and photosynthesis. Consequently, the tree may not fully utilize soil moisture and, thus, may not capitalize fully on periods with high photosynthetic potential.

Furthermore, although conifers are the most productive timber trees in the Pacific Northwest, the growth rate of these species during early years is generally quite slow. For instance, a 26-year-old stand of western hemlock from the Oregon Coast was found to have a current annual biomass production of 11 tons dry weight per acre per year, equal or higher than the most productive world forests, including tropical rain forests. Despite this high rate of production at age 26, the average production for the entire 26-year period of that stand was only 2.9 tons per acre per year. Average production of less rapidly growing stands of conifers would, of course, average even lower.

Several years ago some forest scientists in the Southeast proposed a new approach to forest production for fiber which they called "silage sycamore." The principle of the system was to use a fast-growing tree species, such as sycamore, in very dense plantations with harvest as often as every two years. The advantages of their system as they saw it were that 1) maximum growth rates would be achieved much more rapidly than from conventional forest plantations, 2) elimination of the need to replant after harvest by use of species that would readily resprout following cutting, 3) mechanical harvest with perhaps chipping at time of harvest, thus mechanizing the harvest operation, and 4) production of a relatively uniform product that could be readily transported in vans and could be conveniently handled by conveyor or blower.

Indeed, the first efforts to evaluate yields under such conditions were very encouraging. So much so that it now appears that the short rotation idea was somewhat oversold. To be sure, early yields are high under such a system, but more recent research with sycamore and other species shows higher yields can be obtained when the harvest cycle is increased from two years or so to eight years and more. Furthermore, at the older ages the yield advantage of close spacing is very much reduced. Also, the cost of stand establishment dictates wider spacing. Nevertheless, with today's interest rates, the advantage of shortening rotation time is obvious. Additionally, for the short term at least, resprouting has become a minor factor, since the rapid gains possible from genetic improvement make replacement of planting stock likely after the first or second harvest.

Research on woody biomass plantings

Use of fast growing hardwood species for maximum biomass production continues to receive major emphasis in work on growing woody biomass. Our research was conducted initially with Dwight Peabody, Western Washington Research and Extension Unit in Mount Vernon, and is now being done with Professor Reinhardt Stettler, forest geneticist, University of Washington, Seattle. The major emphasis of this work is with black cottonwood *(Populus trichocarpa)*, the native cottonwood of the Pacific Northwest and a species highly regarded in Europe where cottonwood planting and culture far predates Pacific Northwest efforts. Our attempts to improve the growth rate of black cottonwood include selection and intraspecific crosses with eastern cottonwood *(P. deltoides)*. One such hybrid planted near Sumner at a 10 x 10 foot spacing without irrigation grew 11 feet the first year from a 20-inch cutting planted 18 inches deep. On August 20th, I measured this tree and it was 14.8 inches in diameter at breast height and 87 feet tall and it won't be 9 years old until this winter. This tree resulted from a cross using pollen collected from a superior *P. deltoides* from Mississippi and a randomly selected *P. trichocarpa* from western Washington. Such crosses with black cottonwood are easily made. Branches containing flower buds from a female *P. trichocarpa* are clipped early in the spring, placed in water and when the buds open they are dusted with the select pollen. Using *P. trichocarpa* as the female parent permits production of viable seeds on the clipped branches. In contrast, branches of *P. deltoides* must be grafted to rooted stock in order for viable seed to be produced.

Our first efforts at systematic selection of black cottonwood involved the collection of cuttings from 50 selected wild trees, 5 trees each from 10 stands located on the South along the Santiam River near Albany, Oregon, to the Chilliwak Valley on the North in southern British Columbia. Flowering branches and later seeds from these stands were also collected. The cuttings were planted on an irrigated site near Sumner, Washington, using 45 20-inch cuttings per clone. These were planted at 4 x 4 foot spacing in nine tree rows with five replications. Additionally, five representatives of the material, including hardwoods that we had been working with for some time, were used in the experiment for comparison. Average height growth of the first year for up to 45 individuals per clone ranged from 5.9 to 10 feet. The cuttings from the hybrid I mentioned earlier grew best but several clones of *P. trichocarpa* grew almost as high and were in fact not significantly different in height from the fastest growing hybrid. On August 20th, the best plants of this hybrid were 24 feet tall. These individuals will still grow another meter in height this year and these plants won't be two years old until this winter.

We intend to select not only for biomass production but also for trunk straightness and small branches because such features are likely to be related to effective utilization of growing space as well as timber quality. Thus, we expect that the materials selected for biomass production will also be suitable for timber production.

A feature of our work that I haven't mentioned is growth of mixed stands, primarily cottonwood-red alder mixture. The purpose of such mixtures is to obtain the benefit of nitrogen fixation by alder and perhaps avoid the need for nitrogen fertilization. Accordingly, we have planted 28 clones in a second experiment to test the effects of alder on cottonwood primarily from the standpoint of total biomass yield of the mixture. Earlier Dean DeBell, forest scientist, U. S. Forest Service, Olympia, Washington, reported benefits of such a mixture in terms of enhanced growth of cottonwood. In our experiment, we found after the first year, a significant, although small, increase in nitrogen content of cottonwood foliage on trees grown with alder. This year we have noted a large increase in both total foliage mass and a darker green foliage color in cottonwood associated with the alder. Such a rapid effect from alder was unexpected since the primary means

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for alder to benefit associated plants has been thought to be through the accumulated forest litter and thus is a longer term process. Although inclusion of red alder in such mixtures shows great promise at this time, we have not begun efforts at genetic improvement of that species.

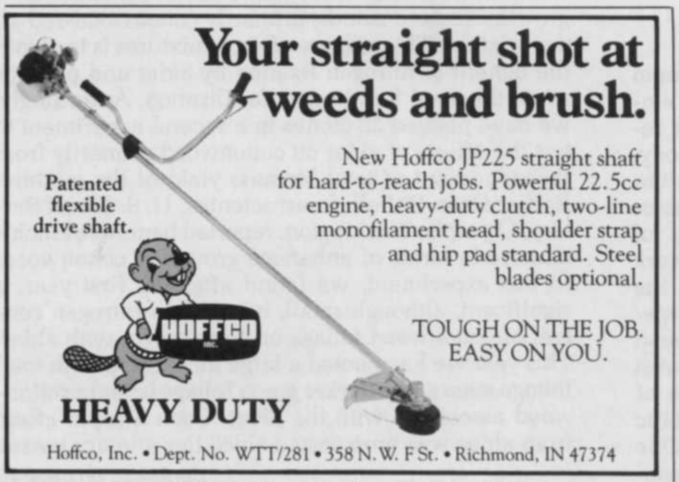
Yields and cultural practices

Highest yields reported to date are from willows in Sweden where 14 dry tons per acre per year are claimed. With irrigation we expect our best cottonwood clone to give similar yields, since our estimated production was 10 tons per acre for the first year. Without irrigation our best yield from wild stock black cottonwood at 4 x 4 foot spacing and for a four-year cutting cycle has been 4.1 dry tons per acre per year. The same material on a drier site with some grass competition gave 2.6 tons per acre per year at the same spacing and harvest cycle.

For satisfactory results, weeds and grass must be controlled at least during the first growing season. We have been satisfied with preplant herbicides or summer fallow together with minimal cultivation the first season. Dwight Peabody at Mount Vernon has tested many herbicides and has only recently had results showing some selectivity for two materials.

Best spacing depends upon rotation age. We recently obtained yields from a single harvest after eight years which averaged 40 percent more than from the combined yields from two four-year harvests. At eight years, yields were relatively independent of spacing up to 4 x 6 foot; whereas, with shorter rotations (four years or less) spacing is very important in the first harvest but less so in subsequent harvests. The major factor determining spacing and rotation age is size of material desired at harvest and this will vary according to harvest methods, markets, and so forth. We expect wide variation in such factors among regions and locations.

All planting is with cuttings, although stands can be readily produced using seedlings. With black cottonwood, cuttings can be of any age material, i.e., branches or sprouts. We use material from ⅜ to 1¼ inches in diameter. Cuttings are about 18 inches long and are placed in subsoiling trenches with about 2 inches left above ground. Such cuttings are collected in the winter months. Survival is high but can be improved for cuttings that have been stored by a 48-hour soak in water. Survival of certain of the hybrids with *P. deltoides* can be much lower, and soaking of these materials is recommended. Mid-season pruning to a single stem is also recommended, although it is not required for short rotation biomass plantings.



Fertilization with nitrogen is required on low organic matter status soils although we have not seen much response to fertilizer in the few instances where we have tried it. We are currently developing foliar analysis guidelines for use in determining nitrogen fertilization requirements.

Diseases have so far not been a problem as long as westside *P. trichocarpa* has been used. Eastside *P. trichocarpa* is not satisfactory for the westside because of the high susceptibility of these materials to a leaf rust under the more humid climate. Insects chew on these plants, but to date we have not felt the need for spraying. Distressed plants—from weed competition, dry soils, and newly planted seedlings—set their buds early in the season and can be severely affected by a bud infesting midge. More vigorous plants set buds much later, especially the terminal bud and by this means appear to avoid being infested.

Conclusions

1. Technology for several processes and end products using biomass to capture solar energy is being developed with the feasibility of each varying with specific growing conditions, needs, and other characteristics of a region or country.
2. Woody plant material is likely to represent a significant portion of the biomass used for energy in most areas.
3. Production of woody biomass offers diversification of markets, including not only energy uses but also pulp chips, cordwood, and timber.
4. Woody species plantations for biomass will likely vary from extensive plantations growing small dimension material in relatively short rotations, such as are planned for Sweden, to small wood lots and fence rows on small ownerships. In these cases, larger dimension trees will likely be grown at longer rotations and wider spacings.
5. Nitrogen fixing plants including trees such as red alder will be utilized in both pure stands and in mixtures with other trees.
6. Tree improvement programs will result in continually improved planting materials with selections and hybrids being developed for specific soil and site conditions.
7. The substantial requirements in land and water to bring about a significant increase in woody biomass production can result only from a new concern for conservation of land and water resources. Loss of productive lands to urbanization and other causes and the generally wasteful usage of irrigation water in this country cannot continue even without the additional water and land needs for biomass plantations. Uncommitted sources of irrigation water including waste water can be used for energy plantations, but a new land and water conservation emphasis will be required if biomass is to be a significant factor for future energy supplies. **WTT**